

# PATENT ABSTRACTS OF JAPAN

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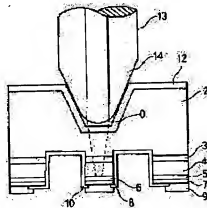
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## (54) OPTICAL SEMICONDUCTOR DEVICE

### (57)Abstract:

PURPOSE: To provide a wide-band optical semiconductor device that can be easily coupled to an optical fiber or rod lens.

CONSTITUTION: An optical semiconductor device includes a semiconductor substrate 2, on which photoelectric regions 3, 4, and 5 are laminated in the direction of optical input or output. The substrate is provided with a photocoupling section having an alignment hole 0 into which an external optical conductor 14 fits tightly. This structure facilitates the alignment of the optical semiconductor device with an optical conductor, decreases the time for production and adjustments, and improves yield. In addition, wide-band applications can be easily realized if the external optical conductor is a rod lens or an end-processed lens.



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**CLAIMS**

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**[Claim(s)]**

- [Claim 1] The optical semiconductor device with which a laminating is carried out on a semi-conductor substrate, and an optical input or the direction of an optical output is characterized by establishing an external light pipe edge and the hole for adjustment optical coupling in which adhesion insertion is possible in the optical coupling section of the above-mentioned substrate in the semi-conductor laminated structure which has a vertical photo-electric-translation field to the direction of a laminating.
- [Claim 2] The optical semiconductor device which the shape of a taper with the above-mentioned hole for optical coupling equal to the taper angle of a point ball processing optical fiber and the depth are processed in an optical semiconductor device according to claim 1 so that the focus of the above-mentioned point ball processing optical fiber may come to the above-mentioned photo-electric-translation field, and is characterized by a photo-electric-translation field being a light sensing portion.
- [Claim 3] The optical semiconductor device which the above-mentioned hole for optical coupling has a bore equal to the above-mentioned diameter of a dot lens, and the depth is processed in an optical semiconductor device according to claim 1 so that the focus of the above-mentioned dot lens may come to the above-mentioned photo-electric-translation field, and is characterized by a photo-electric-translation field being a light sensing portion.
- [Claim 4] The optical semiconductor device characterized by the above-mentioned photo-electric-translation field being the light sensing portion of the PIN structure which impressed the reverse bias electrical potential difference to the PN junction in an optical semiconductor device according to claim 1, 2, or 3.
- [Claim 5] The optical semiconductor device characterized by being the light sensing portion which the above-mentioned photo-electric-translation field becomes from the multiplication layer using the avalanche multiplication device in the PN-junction section, and an optical absorption layer in an optical semiconductor device according to claim 1, 2, or 3.
- [Claim 6] The optical semiconductor device characterized by the above-mentioned multiplication layer being a superstructure in an optical semiconductor device according to claim 5.
- [Claim.7] The optical semiconductor device with which claim 1 thru/or an optical semiconductor device given in six are characterized by carrying out flip chip mounting at other semiconductor devices which carried the electronic circuitry.
- [Claim 8] The optical semiconductor device characterized by an optical input or the direction of an optical output prepare the hole for adjustment optical coupling in which an external light pipe edge and adhesion insertion in the optical coupling section corresponding to the photo electric translation field of the above-mentioned semi-conductor substrate be possible on a semi-conductor substrate in the optical semiconductor device with which it have an electronic circuitry relevant to at least one and the above-mentioned photo electric translation field for a vertical photo electric translation field to the direction of a laminating .
- [Claim 9] The optical semiconductor device which the shape of a taper with the above-mentioned hole for optical coupling equal to the taper angle of a point ball processing optical fiber and the depth are processed into the depth for which the focus of the above-mentioned point ball processing optical fiber

comes to the above-mentioned photo-electric-translation field in an optical semiconductor device according to claim 8, and is characterized by a photo-electric-translation field being a light sensing portion.

[Claim 10] The optical semiconductor device which the above-mentioned hole for optical coupling has a bore equal to the above-mentioned diameter of a dot lens, and the depth is processed in an optical semiconductor device according to claim 8 so that the focus of the above-mentioned dot lens may come to the above-mentioned photo-electric-translation field, and is characterized by a photo-electric-translation field being a light sensing portion.

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#### DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the structure of an optical semiconductor device and the semiconductor device which combines the external light pipe of the optical semiconductor device which has the part which carries out conversion or an electrical signal to an electrical signal, and carries conversion or its both out for a lightwave signal to a lightwave signal if it says in more detail.

[0002]

[Description of the Prior Art] A long distance and a mass fiber-optic transmission system spread quickly in recent years, and 1.6 Gb/s and a 1.7 Gb/s lightwave transmission system are put in practical use in current. Furthermore large capacity-ization of a system is \*\*\*\*(ed) and researches and developments of the lightwave transmission system in which 10 Gb/s optical transmission is possible are active. On the other hand, unlike the old optical transmission method, the so-called researches and developments of the coherent light transmission system which performs mass optical transmission using the property as a wave of light are also active in recent years. The broadband property of several GHz or more is required of the photo detector used for such a mass lightwave transmission system. Therefore, low capacity-ization of a component changes that it is indispensable and diameter[ of small light-receiving ]-izing of an electric eye and a photogenic organ and reduction of parasitic capacitance change with the important technical technical problem. For example, electronics Letters The photo detector of the rear-face light incidence with a monolithic integration micro lens aiming at the miniaturization of a photo detector and broadband-izing is indicated by the 110th page (Electronics Letters vol.24, No.2 (1988) pp 109-110) from the 24th volume, No. 2 (1988), and the 109th page.

[0003] Drawing 2 shows the structure of the photo detector indicated by the above-mentioned reference. The laminating of the n-InP buffer layer 3 (micrometers [ of thickness / 1.5 ], n= 1015-/cm3), the n-InGaAs optical absorption layer 4 (micrometers [ of thickness / 1.9 ], n= 1015-/cm3), and the n-

InP cap layer 5 (micrometers [ of thickness / 1.0 ],  $n = 1016 / \text{cm}^3$ ) is carried out to  $n^+$ -InP substrate top 2, the pn junction formation-back is formed by Zn diffusion, and the mesa structure of about 15 micrometerphi is formed by chemical etching. The SiN film 10 for passivation, the Au system p contact layer 8, and after forming the Au system n contact layer 7 similarly, a substrate 2 is thinly ground to about 70 micrometers, and the micro lens 11 is formed by Ar ion beam etching. The focal distance of a micro lens 11 is 55 micrometers of radius of curvature according to the optical absorption layer 4. Furthermore, the SiN antireflection film 12 is formed on the micro lens 11. Consequently, dark current 30nA, component capacity 20fF, 84% of quantum efficiency, the low dark current of 17.7GHz of 3dB cut off frequencies, low component capacity, and a high bandwidth property have been acquired by bias voltage 10V. About 3 times [ in case the alignment tolerance of a lightwave signal input fiber is a flat component without a lens ] as many 33 micrometers as this are realized by furthermore having integrated the micro lens.

[0004]

[Problem(s) to be Solved by the Invention] The above-mentioned conventional technique was enough taken into consideration about the improvement of the high-speed response characteristic by component capacity reduction, i.e., broadband-izing, in order that it may enlarge alignment tolerance of the optical fiber by diameter [ of small light-receiving ]-izing in accordance with component capacity reduction, is integrating a micro lens and has acquired 3 times as many tolerance as this compared with the case where there is no lens. However, compared with a photo detector with the alignment tolerance 50 micrometers or more conventionally used by optical communication, it cannot say that it is enough, but the yield in a modularization process falls. Moreover, like balance DORESHIBA of coherent optical communication, or future multi-access light INTAKONEKUTO, when integration of many OPTO semiconductor devices is required, when processing of a component becomes complicated, that alignment with an optical fiber is also complicated, and since it becomes what requires time amount; with the above-mentioned conventional technique, there are problems, such as an increment in the production time in a component processing process and a modularization process and adjustment time amount and yield lowering. The object of this invention is solving such a problem and offering the optical large semiconductor device of alignment tolerance with an external light pipe. other objects of this invention -- alignment tolerance with an external light pipe -- large -- the same -- diameter [ of small light-receiving ]-izing of a photo detector -- a broadband -- it is in offering the optical semiconductor device [-izing / a semiconductor device ].

[0005]

[Means for Solving the Problem] In order to attain the above-mentioned object, in this invention, the above-mentioned light pipe edge which can adhesion insert external light pipe edges, such as a fiber for optical coupling or a lot lens, and the hole for optical coupling to adjust were prepared on the substrate of an optical semiconductor device with the semi-conductor laminated structure which has a photo-electric-translation field. An external light pipe edge and a hole with the depth for which the focus of a point ball processing optical fiber or a rod lens comes to the above-mentioned photo-electric-translation field as a desirable target gestalt which prepares the hole for optical coupling to adjust are prepared here.

[0006]

[Function] Since the optical semiconductor device of this invention is adjusted so that it may have the hole which can adhesion insert the external light pipe edge for optical coupling in a semi-conductor substrate and the focus of an optical coupling system may come to a photo-electric-translation field, the optical coupling by which whose alignment was unnecessary and was stabilized is obtained. Since the hole for optical coupling is formed of etching of the mask pattern used in the usual semi-conductor process, the alignment precision with the above-mentioned photo-electric-translation field is settled in about 2-3 micrometers. Since the beam waist of a point ball processing optical fiber is about 5 micrometers, if there are 10 micrometers of diameters of a photo-electric-translation field, they are

enough. Therefore, simple and stable optical coupling are realized by the low capacity high-speed photo detector of 10 micrometers of diameters of light-receiving.

[0007]

[Example] Hereafter, the example of this invention is explained.

Example 1 drawing 1 is condition \*\*\*\* equipped with the edge of the point ball processing fiber which is the sectional view showing the configuration of the 1st one example of the optical semiconductor device by this invention, and is an external light pipe. The edge of a point ball processing fiber has the taper section to which a head core results the partial spherical surface in the diameter of a fiber from nothing and the partial spherical surface like a graphic display. First, manufacture of an optical semiconductor device is explained. A front face is the shape of an  $n(+)$ -InP substrate 2 (it is shown that  $(+)$  is high concentration) of a field (100). the following -- being the same -- MOCVD -- law -- the  $n$ -InP buffer layer 3 (micrometers [ of thickness / 1.2 ],  $n = 1015\text{-}/\text{cm}^3$ ) -- The laminating of the  $n$ -InGaAs optical absorption layer 4 (micrometers [ of thickness / 2.0 ],  $n = 1015\text{-}/\text{cm}^3$ ) and the  $n$ -InP cap layer 5 (micrometers [ of thickness / 1.0 ],  $n = 1016\text{-}/\text{cm}^3$ ) was carried out one by one, Zn thermal diffusion layer 6 was formed, and about 10-micrometer mesa structure was formed by chemical etching after forming pn junction. In addition, above-mentioned each class can also be formed by vapor growth, the liquid phase grown method, and also the MBE method. subsequently, a CVD method -- the SiN film 10 for passivation, and Au system contact layer 8 -- similarly the Au system n contact layer 7 was formed with vacuum deposition. Respectively, in order to take ohmic contact, Ti/Au was used for the ingredient of Ti/Au and n contact layer 7 at the ingredient of p contact layer 8. In addition, the electrode material which can take ohmic junction of p like AuGeNi and AuZn and n both-sexes semi-conductor can also be used. What is necessary is just to choose the passivation film from the ingredient of Si and PSG from the dark current property of a component, and SiO<sub>2</sub> grade.

[0008] Next, formation of the hole 14 for optical coupling is described. After grinding the substrate 2 . . . bottom (on a drawing) which passed through the above-mentioned process to about 150 micrometers, the hole 14 to a depth of about 120 micrometers is formed so that the beam waist of the output light of an optical fiber may come to a photo-electric-translation field by chemical etching using the mask hole pattern of the diameter of 10 micrometerphi. The hole of a circle configuration was mostly formed using the bromine system which does not almost have an anisotropy in an etching reagent. In this case, it becomes 60 mesa \*\*\*\* according to the effectiveness of side etching, and the diameter at the maximum equator of a hole 2 has become about 140 micrometerphi. Since this adjusts the point 14 of the point ball processing fiber 13 ground on the taper square at 60 degrees with the configuration of the above-mentioned hole for association, there is no GURATSUKI and the optical fiber which is an outer conductor after inserting the above-mentioned fiber in a hole 14 can be fixed to stability at an optical semiconductor device. In addition, the ion milling method is also possible for etching. Then, an antireflection film 12 is formed in substrate 2 rear face, and degradation of the optical coupling by echo with a substrate 2 is prevented.

[0009] A photo detector is changed into a reverse bias condition through electrodes 7 and 8. It converges according to an operation of the lens of an edge 14, incidence is carried out through an antireflection film 12 so that a beam waist may come to the optical absorption layer 4, and it is changed into absorption and an electrical signal in the InGaAs optical absorption layer 4, and the lightwave signal (wavelength is 1.3 or 1.55-micrometer band) from the point ball processing fiber 13 is slack. The changed electrical signal is sent out outside from an electrode 8. The properties acquired by this example are component capacity 15ff, dark current 20nA, 85% of quantum efficiency, the high speed of 19GHz of 3dB cut off frequencies, and low noise actuation. Optical coupling only inserted the point ball processing fiber in the predetermined joint hole, and was very easy, and 85% of quantum efficiency was acquired by stability.

[0010] Example 2 drawing 3 is a sectional view showing the configuration of other examples of the optical semiconductor device by this invention. This example is especially effective when loss with a

substrate cannot be disregarded to the light wave length who applies by the rear-face incidence method photo detector. The example shown in drawing 1 is different, and, in the case of a p(+)-InP substrate, is. Ten or more times, for a certain reason, since [ of a n-InP substrate ] substrate thickness will become thick effectually if it is made the shape of a micro lens like the conventional example, loss of a lightwave signal increases, and absorption with a wavelength of 1.3-1.55 micrometers causes decline in quantum efficiency. This example consists of a light sensing portion which consists of a multiplication layer for which the photoelectrical converter used the avalanche multiplication device in the PN-junction section, and an optical absorption layer, and the above-mentioned multiplication layer consists of superstructures.

[0011] a front face — the p(+)-InP substrate 19 top of a field (100) — MBE — law — the Be dope p-InAlAs layer 20 (micrometers [ of thickness / 1.0 ],  $n = 2 \times 10^{18} / \text{cm}^3$ ) — The InGaAs optical absorption layer 21 (micrometers [ of thickness / 1.8 ],  $n = 2 \times 10^{15} / \text{cm}^3$ ), InAlAs electric-field relaxation layer 22 (0.2 micrometer [ of thickness ],  $n = 5 \times 10^{16} / \text{cm}^3$ ) 22, and the InAlAs/InGaAs superlattice redoubling layer 23 (micrometers [ of thickness / 0.6 ], and  $n < 1 \times 10^{15} / \text{cm}$ ) — 15nmInAlAs barrier layer, 15nmInGaAs redoubling layer, a period 20, The Si dope n-InAlAs layer 24 (micrometers [ of thickness / 1.0 ],  $n = 2 \times 10^{18} / \text{cm}^3$ ), After carrying out sequential continuation growth of the InGaAs contact layer 25 (micrometers [ of thickness / 0.2 ],  $n = 5 \times 10^{18} / \text{cm}^3$ ), the mesa structure of the diameter of about 10 micrometerphi is formed using a dichromic acid system etching reagent. Vacuum deposition of the n electrode 26 and the p electrode 27 is carried out. Here, Ti/Au was used for AuZn/Pt/Au and p electrode material like the example of drawing 1 at n electrode material. The antireflection film 29 was formed for the poly MIIDO insulation protective coat 28 in the rear face of a substrate 19 at the mesa section, respectively. An external light pipe edge consists of lot lenses, and the hole 14 for adjustment optical coupling is constituted in the shape of a cylinder so that the adhesion insertion of the lot lens edge can be carried out. Depth setting out of the depth of a cylinder-like hole is carried out so that the beam waist of the output light of a lot lens may come to a photo-electric-translation field. the properties of the avalanche multiplication photo detector out of which this example could come are the high speed of 10GHz or more of 3dB cut off frequencies, and a low noise in component capacity 20FF, dark current 40nA, 75% of quantum efficiency, and a multiplication factor 10.

[0012] Example 3 drawing 4 is the sectional view showing the configuration of the example of further others of the optical semiconductor device by this invention. This example includes the photo detector of the example shown in drawing 1 in the circuit board 15. In drawing, the same number is given to the same part as the photo detector of the example shown in drawing 1. The circuit board 15 has the electronic-circuitry pattern 16 for supplying bias to a photo detector and taking out an electrical signal, and has prepared the electrical connection of the electronic-circuitry pattern 16 and a photo detector the pewter bump 17. The face down of the photo detector is carried out, it places on the circuit board 15 like a graphic display, and heats with a hot plate, a pewter bump is melted, and connection immobilization is carried out with a photo detector and the circuit pattern 16. The point of an optical fiber (not shown) carries out insertion immobilization by viewing in the hole 14 for optical coupling. Thus, by adopting the structure of this invention, flip chip mounting which makes the bonding wire for electrical connection unnecessary is attained, and there is no degradation of the RF property under the effect of a parasitism inductance, and the external light pipe and the optical semiconductor device with which optical coupling is obtained easily were realized.

[0013] Although the above explanation explained the example of a photo detector with especially effective this invention, this invention is not limited to the above-mentioned example. It contains, also when the thing and photo-electric-translation field which were combined with a photo detector and other semiconductor devices constitute a light-emitting part. Namely, the optical coupling holes 30 and 31 of the optical coupling hole 31 grade congener the optical coupling hole 30 for photo detectors and for light emitting devices or the plurality for [ of a different kind ] components are established in semiconductor integrated circuit equipment like drawing 5. When forming the electrical circuits 32 and

33 combined with these components 30 and 31 in semiconductor integrated circuit equipment, with the laser component in which a semiconductor device has an optical resonator like drawing 6 When the optical coupling hole 31 is formed near the luminescence side of a semiconductor laser component, the case where it is in the location where the optical output section of an optical semi-conductor separated from the luminescence surface part of laser like drawing 7 etc. is included.

[Effect of the Invention] According to this invention, by establishing the hole for the optical system for combining a lightwave signal with the photo-electric-translation field prepared in the semi-conductor laminated structure of an optical semiconductor device in a semi-conductor substrate side so that the configuration of the above-mentioned optical system may be suited, the stable optical coupling can be obtained, for this reason, a photo-electric-translation field can be made into necessary minimum magnitude for the tolerance of optical coupling, and the improvement in a component property, especially improvement in the speed can be promoted. Since an optical coupling system comes to a substrate background, flip chip mounting is attained, and good high-speed responsibility can be realized by the photogenic organ and the electric eye. Moreover, since adjustments, such as alignment of optical coupling, are lost, the yield improves. This is especially advantageous when there are two or more components.

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#### DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the sectional view of one example of the OPTO semiconductor device by this invention.

[Drawing 2] It is the sectional view of one example of the conventional carrier semi-conductor light corpuscle child.

[Drawing 3] It is the sectional view of other examples of the OPTO semiconductor device by this invention.

[Drawing 4] It is the sectional view of one example of the optical semiconductor device by this invention.

[Drawing 5] It is the sectional view of other examples of the optical semiconductor device by this invention.

[Drawing 6] It is the sectional view of one example of the light emitting device by this invention.

[Drawing 7] It is the sectional view of other examples of the light emitting device by this invention.

[Description of Notations]

0, 30, 31 — Adjustment optical coupling hole,

2 19 — p(+)-InP substrate,

3 — InP buffer layer,

4 21 — InGaAs absorption layer,

5 — InP cap layer,

- 6 -- Zn diffusion layer,
  - 7 -- n contact layer,
  - 8 -- p contact layer
  - 9 -- Bonding pad,
  - 10 -- SiN layer,
  - 12 29 -- SiN antireflection film,
  - 13 -- Optical fiber
  - 14 -- External light pipe edge,
  - 15 -- Circuit board,
  - 16 -- Circuit pattern,
  - 17 -- Solder bump,
  - 20 -- p-InAlAs layer,
  - 22 -- InAlAsP layer,
  - 23 -- InAlAs/InGaAs superlattice multiplication layer,
  - 24 -- InAlAs layer,
  - 25 -- InGaAs contact layer,
  - 26 -- n electrode,
  - 26 -- p electrode,
  - 28 -- The poly MIIDO layer.
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[Translation done.]

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## (54) 【発明の名称】 光半導体装置

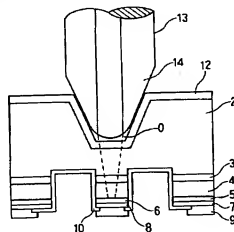
## (57) 【要約】

【目的】 光ファイバ、ロットレンズ等の光導体と結合が容易でかつ広帯域特性を持つ光半導体装置を得る。

【構成】 半導体基板(2)上に光入力又は光出力方向が積層方向にたいし垂直である光電変換領域(3、4、5)を積層した光半導体装置において、上記基板(2)の光結合部に外部光導体端部(14)と密着挿入可能な整合光結合用穴(0)を設けた。

【効果】 光半導体装置と外部光導体とのアライメントが簡単となり、素子加工工程、モジュール化工程での生産時間、調整時間の短縮及び歩留まりが向上する。また外部光導体低下がロットレンズ、先端加工レンズのとき、光半導体装置の広帯域化が容易となる。

図1



0...整合光結合穴

2...n<sup>+</sup>-InP基板

3...InPバッファ層

4...InGaAs 吸収層

5...InP キップ層

6...Zn 拡散層

7...p コンタクト層

8...p コンタクト層

9...ボンディングパッド

10...SiN 膜

12...SiN 反射防止膜

13...光ファイバ

14...外部光導体端部

(2)

## 【特許請求の範囲】

【請求項1】 半導体基板上に積層され、光入力又は光出力方向が積層方向にたいし垂直である光電変換領域を有する半導体積層構造において、上記基板の光結合部に外部光導体端部と密着挿入可能な整合光結合用穴を設けたことを特徴とする光半導体装置。

【請求項2】 請求項1記載の光半導体装置において、上記光結合用穴が先球加工光ファイバのテーパ角と等しいテーパ状、かつ、深さが上記光電変換領域に上記先球加工光ファイバの焦点がくるように加工され、光電変換領域が受光部であることを特徴とする光半導体装置。

【請求項3】 請求項1記載の光半導体装置において、上記光結合用穴が上記ドットレンズ径と等しい内径を持ち、かつ、深さが上記光電変換領域に上記ドットレンズの焦点がくるように加工され、光電変換領域が受光部であることを特徴とする光半導体装置。

【請求項4】 請求項1、2又は3記載の光半導体装置において、上記光電変換領域がPN接合に逆バイアス電圧を印加したPIN構造の受光部であることを特徴とする光半導体装置。

【請求項5】 請求項1、2又は3記載の光半導体装置において、上記光電変換領域がPN接合部でのなだれ増倍機構を利用した増倍層と光吸収層からなる受光部であることを特徴とする光半導体装置。

【請求項6】 請求項5記載の光半導体装置において、上記増倍層が超格子構造であることを特徴とする光半導体装置。

【請求項7】 請求項1ないし6記載の光半導体装置が電子回路を搭載した他の半導体装置にフリップ・チップ実装されたことを特徴とする光半導体装置。

【請求項8】 半導体基板上に、光入力又は光出力方向が積層方向にたいし垂直である光電変換領域を少なくとも1つと、上記光電変換領域と関連する電子回路を有する光半導体装置において、

上記半導体基板の光電変換領域に対応する光結合部に外部光導体端部と密着挿入可能な整合光結合用穴を設けたことを特徴とする光半導体装置。

【請求項9】 請求項8記載の光半導体装置において、上記光結合用穴が先球加工光ファイバのテーパ角と等しいテーパ状、かつ、深さが上記光電変換領域に上記先球加工光ファイバの焦点がくる深さに加工され、光電変換領域が受光部であることを特徴とする光半導体装置。

【請求項10】 請求項8記載の光半導体装置において、上記光結合用穴が上記ドットレンズ径と等しい内径を持ち、かつ、深さが上記光電変換領域に上記ドットレンズの焦点がくるように加工され、光電変換領域が受光部であることを特徴とする光半導体装置。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】 本発明は光半導体装置、更に詳し

く言えば、光信号を電気信号に変換又は電気信号を光信号に変換、又はその両方を行なう部分をもつ光半導体装置の外部光導体とを結合する半導体装置の構造に関するものである。

## 【0002】

【従来技術】 長距離、大容量の光ファイバ伝送システムは近年、急速に普及し、現在では1.6Gb/s、1.7Gb/s光伝送システムが実用化されている。さらにシステムの大容量化を目差し、10Gb/s光伝送が可能な光伝送システムの研究開発が活発になっている。一方、今までの光伝送方式と異なり、光の波としての性質を利用して大容量光伝送を行なう、いわゆるコヒーレント光伝送システムの研究開発も近年活発になっている。このよう大容量光伝送システムに用いる受光素子には数GHz以上の広帯域特性が要求される。そのために素子の低容量化が必須と成り、受光器、発光器の小受光径化及び寄生容量の低減が重要技術課題と成っている。例えば、エレクトロニクス・レターズ 第24巻、第2号(1988年)、第109頁から第110頁 (Electronics Letters vol.24, No.2(1988) pp109-110)には、受光素子の小型化、広帯域化を目的としたモノリシック集積化マイクロレンズ付き裏面入射の受光素子が記載されている。

【0003】 図2は上記文献に記載された受光素子の構造を示す。n(+)-InP基板上にn-InPバッファ層3(膜厚1.5 $\mu$ m、 $n=1.015/cm^3$ )、n-InGaAs光吸収層4(膜厚1.9 $\mu$ m、 $n=1.015/cm^3$ )、n-InPキャップ層5(膜厚1.0 $\mu$ m、 $n=1.016/cm^3$ )を積層し、Zn拡散によりpn接合を形成後、化学エッチングにより、約15 $\mu$ m $\phi$ のメサ構造を形成する。パッシベーション用Si<sub>3</sub>N<sub>4</sub>膜10、Au系pコンタクト層8、同じくAu系nコンタクト層7を設けた後、基板2を約70 $\mu$ mまで薄く研磨し、Arイオン・ビーム・エッチングによりマイクロレンズ11を形成している。マイクロレンズ11の焦点距離は、光吸収層4に合せて、曲率半径径55 $\mu$ mである。さらにマイクロレンズ11の上にSi<sub>3</sub>N<sub>4</sub>反射防止膜12を設けられている。この結果、バイアス電圧10Vで暗電流30nA、素子容量20fF、量子効率84%、3dBカットオフ周波数17.7GHzの低暗電流、低素子容量、高帯域特性を得ている。さらにマイクロレンズを集積化したことにより光信号入力ファイバのアライメント許容度がレンズのない平坦な素子の場合の約3倍の33 $\mu$ mを実現している。

## 【0004】

【発明が解決しようとする課題】 上記従来技術は、素子容量低減による高速応答特性の改善、即ち広帯域化について十分考慮され、素子容量低減に伴う小受光径化による光ファイバのアライメント許容度を大きくするため、マイクロレンズを集積化することで、レンズがない場合に比べ3倍の許容度を得ている。しかし、従来光通信

(3)

で用いられている50 $\mu\text{m}$ 以上のアライメント許容度を持つ受光素子に比べ十分とは言えず、モジュール化工程での歩留まりが低下する。又、コヒーレント光通信のパラシトドレーバや将来のマルチアクセス光インターコネクタのように多数の光半導体素子の集積化が必要な場合、上記従来技術では素子の加工が複雑になる上、光ファイバとのアライメントも複雑かつ時間を要するものとなるため、素子加工工程、モジュール化工程での生産時間、調整時間の増加、及び歩留まり低下などの問題がある。本発明の目的はこの様な問題を解決し、外部光導体とのアライメント許容度の大きい光半導体装置を提供することである。本発明の他の目的は外部光導体とのアライメント許容度の大きく、同じ受光素子の小受光径化により広帯域化可能な光半導体装置を提供することにある。

【0005】

【課題を解決するための手段】上記目的を達成するため本発明では、光電変換領域を有する半導体積層構造をもつ光半導体装置の基板上に、光結合用ファイバ又はロッドレンズ等の外部光導体端部を密着挿入可能な、上記光導体端部と整合する光結合用穴を設けた。ここで外部光導体端部と整合する光結合用穴を設ける好ましい形態としては、先球加工光ファイバ又はロッドレンズの焦点が上記光電変換領域にくるような深さを持つ穴を設ける。

【0006】

【作用】本発明の光半導体装置は、半導体基板に光結合用の外部光導体端部を密着挿入可能な、穴を有し、光結合系の焦点が光電変換領域に来るように調整されているので、アライメントが不要かつ安定した光結合が得られる。光結合用の穴は通常の半導体プロセスで用いるマスクパターンのエッチングにより形成されるので上記光電変換領域と位置合わせ精度は2~3 $\mu\text{m}$ 程度で収まる。先球加工光ファイバのビームウエストは5 $\mu\text{m}$ 程度であるから光電変換領域径は10 $\mu\text{m}$ あれば十分である。したがって、受光径10 $\mu\text{m}$ の低容量高速受光素子で簡便かつ安定した光結合が実現される。

【0007】

【実施例】以下、本発明の実施例について説明する。

実施例1

図1は、本発明による光半導体装置の第1の実施例の構成を示す断面図で、外部光導体である先球加工ファイバの端部を装着した状態を示す。先球加工ファイバの端部は図示のように、先端中心部が部分球面をなし、部分球面からファイバ径にいたるテーパ部を持つ。まず、光半導体装置の製造について説明する。表面が(100)面のn(+)-InP基板2(+)は高濃度であることを示す(以下同じ)にMOCVD法によりn-InPパッパ層3(膜厚1.2 $\mu\text{m}$ ,  $n=1.0^{15}/\text{cm}^3$ )、n-InGaAs光吸収層4(膜厚2.0 $\mu\text{m}$ ,  $n=1.0^{15}$

$/\text{cm}^3$ )、n-InPキャップ層5(膜厚1.0 $\mu\text{m}$ ,  $n=1.0^{16}/\text{cm}^3$ )を順次積層し、Zn熱拡散層6を設け、pn接合を形成後、化学エッチングにより、約10 $\mu\text{m}$ のメサ構造を形成した。なお、上記各層は気相成長法や液相成長法更にはMBE法によって形成することもできる。次いで、CVD法によりパッシベーション用SiN膜10、Au系コンタクト層8、同じくAu系コンタクト層7を真空蒸着により設けた。それぞ、オーミック接続をとるために、pコンタクト層8の材料にはTi/Au、コンタクト層7の材料にはTi/Auを用いた。なお、AuGeNi、AuZnのようなp、n両性半導体ともオーミック接合のとれる電極材料を用いることもできる。パッシベーション膜は素子の暗電流特性からSi、PSG、SiO<sub>2</sub>等の材料から選べば良い。

【0008】次に光結合用穴14の形成についてのべる。上記工程を終った基板2の下側(図面の右側)を約150 $\mu\text{m}$ 程度まで研磨した後、10 $\mu\text{m}$ φのマスクパターンを利用して化学エッチングにより光ファイバの出力光のビームウエストが光電変換領域に来るように深さ約120 $\mu\text{m}$ 程度までの穴14を形成する。エッチング液に異方性がほとんどない臭素系を用い、ほぼ円形状の穴を形成した。この場合、サイドエッチングの効果によりメサ角約60度となり、穴2の最大直径は約140 $\mu\text{m}$ φとなっている。これにより、60度にテーパ角で研磨した先球加工ファイバ13の先端部14は上記結合用穴の形状と整合するので、上記ファイバを穴14に挿入後の外部導体である光ファイバをグラツキなく、安定に光半導体装置に固定できる。なお、エッチングはイオンミリング法などでも可能である。この後、反射防止膜12を基板2裏面に設け、基板2での反射による光結合の劣化を防止する。

【0009】電極7、8を介して受光素子を逆バイアス状態にする。先球加工ファイバ13からの光信号(波長は1.3又は1.55 $\mu\text{m}$ 帯)は、端部14のレンズの作用により受取られ、光吸収層4にビームウエストがくるように反射防止膜12を介して入射され、InGaAs光吸収層4で吸収、電気信号に変換される。変換された電気信号は、電極8より外部に送出される。本実施例で得られた特性は、素子容量15fF、暗電流20nA、量子効率85%、3dBカットオフ周波数19GHzの高速、低雑音動作である。光結合は先球加工ファイバを所定の結合穴に挿入するだけで、極めて簡単でかつ安定に量子効率85%が得られた。

【0010】実施例2

第3図は本発明による光半導体装置の他の実施例の構成を示す断面図である。本実施例は、裏面入射方式受光素子で適用する光波長にたいし基板での損失が無視できない場合、特に有効である。図1に示した実施例とは違

てp(+)-InP基板の場合、波長1.3~1.55

(4)

$\mu\text{m}$ の吸収は $n\text{-InP}$ 基板の10倍以上あるため、従来例のようにマイクロレンズ状にすると実効的に基板厚が厚くなるため光信号の損失が増加し、量子効率の低下を招く。本実施例は光電変換部が $\text{P-N}$ 接合部でのなだらけ増倍機構を利用した増倍層と光吸収層からなる受光部からなり、上記増倍層が超格子構造で構成されている。

【0011】表面が(100)面の $\text{p}(\text{H})\text{-InP}$ 基板19の上に、MBE法により $\text{Be-dp-InAlAs}$ 層20(膜厚 $1.0\mu\text{m}$ ,  $n=2\times 10^{18}/\text{cm}^3$ )、 $\text{InGaAs}$ 光吸収層21(膜厚 $1.8\mu\text{m}$ ,  $n=2\times 10^{15}/\text{cm}^3$ )、 $\text{InAlAs}$ 電界緩和層22(膜厚 $0.2\mu\text{m}$ ,  $n=5\times 10^{16}/\text{cm}^3$ )、 $\text{InAlAs}/\text{InGaAs}$ 超格子倍増層23(膜厚 $0.6\mu\text{m}$ ,  $n<1\times 10^{15}/\text{cm}$ ,  $15\text{nmInAlAs}$ 障壁層、 $15\text{nmInGaAs}$ 倍増層、周期20)、 $\text{Si-dp-n-InAlAs}$ 層24(膜厚 $2.0\mu\text{m}$ ,  $n=2\times 10^{18}/\text{cm}^3$ )、 $\text{InGaAs}$ コンタクト層25(膜厚 $0.2\mu\text{m}$ ,  $n=5\times 10^{18}/\text{cm}^3$ )を順次連続成長させた後、重クロム酸系エッチング液を用いて、約 $10\mu\text{m}$ 径のメサ構造を形成する。 $n$ 電極26、 $p$ 電極27を真空蒸着する。ここでは図1の実施例同様、 $n$ 電極材料には $\text{AuZn}/\text{Pt}/\text{Au}$ 、 $p$ 電極材料には $\text{Ti}/\text{Au}$ を用いた。メサ部にポリミド絶縁保護膜28を、基板19の裏面には反射防止膜29をそれぞれ設けた。外部光導体端部がロットレンズで構成され、整合光結合用穴14は、ロットレンズ端部が密着挿入できるように円柱状に構成されている。円柱状の穴の深さは、ロットレンズの出力光のビームウェストが光電変換領域に来るように深さ設定されている。本実施例ではえられたアランシエ増倍受光素子の特性は、素子容量 $20\text{fF}$ 、暗電流 $40\text{nA}$ 、量子効率 $75\%$ 、増倍率 $10$ で $3\text{dB}$ カットオフ周波数 $10\text{GHz}$ 以上の高速、低雑音である。

#### 【0012】実施例3

図4は、本発明による光半導体装置の更に他の実施例の構成を示す断面図である。本実施例は図1に示した実施例の受光素子を回路基板15に組み込んだものである。図において、図1に示した実施例の受光素子と同一部分には同一の番号を付している。回路基板15は、受光素子へバイアスを供給し電気信号を取り出すための電子回路パターン16を有し、電子回路パターン16と受光素子の電気接続部にハンダバンプ17を設けてある。受光素子をフェイスダウンして図示のように回路基板15上に置き、ホットプレートで加熱しハンダバンプを溶かして受光素子と回路パターン16と接続固定する。光ファイバー(図示せず)の先端部は光結合用穴14に目視により挿入固定する。このように本発明の構造を採用することにより、電気接続用のボンディングワイヤを不要とするフリップチップ実装が可能となり、寄生インダクタンスの影響による高周波特性の劣化がなく、かつ外部光

導体と容易に光結合が得られる光半導体装置を実現した。

【0013】以上の説明は本発明が特に有効な受光素子の例について説明したが、本発明は上記実施例に限定されるものではない。受光素子と他の半導体装置と組み合わせたもの、光電変換領域が発光部を構成する場合も含む。即ち図5のように半導体集積回路装置に受光素子用の光結合穴30、発光素子用の光結合穴31等種々又は異種の素子用の複数の光結合穴30、31を設け、半導体集積回路装置内にこれらの素子30、31と結合した電気回路32、33を形成する場合、図6のように半導体装置が光共振器をもつレーザ素子で、光結合穴31が半導体レーザ素子の発光面近くに形成される場合、図7のように光半導体の光出力部がレーザの発光面部から離れた位置にある場合等含む。

【発明の効果】本発明によれば、光半導体装置の半導体積層構造内に設けられた光電変換領域に光信号を結合させるための光学系用の穴を上記光学系の形状にあうように半導体基板側に設けることにより、安定した光結合が得られ、このため光結合のトランズのために光電変換領域を必要最小限の大きさにすることができ、素子特性向上、特に高速化を促進できる。光結合系が基板裏側に来るのでフリップチップ実装が可能となり、発光器、受光器で良好な高速応答性が実現できる。又、光結合の位置合わせなど調整がなくなるので歩留まりが向上する。これは素子が複数ある場合、特に有利である。

#### 【図面の簡単な説明】

【図1】本発明による光半導体素子の一実施例の断面図である。

【図2】従来の受半導体光素子の一実施例の断面図である。

【図3】本発明による光半導体素子の他の実施例の断面図である。

【図4】本発明による光半導体装置の一実施例の断面図である。

【図5】本発明による光半導体装置の他の実施例の断面図である。

【図6】本発明による発光素子の一実施例の断面図である。

【図7】本発明による発光素子の他の実施例の断面図である。

#### 【符号の説明】

- 0、30、31…整合光結合穴、
- 2、19… $\text{p}(\text{H})\text{-InP}$ 基板、
- 3… $\text{InP}$ バッファ層、
- 4、21… $\text{InGaAs}$ 吸収層、
- 5… $\text{InP}$ キャップ層、
- 6… $\text{Zn}$ 拡散層、
- 7… $n$ コンタクト層、
- 8… $p$ コンタクト層

(5)

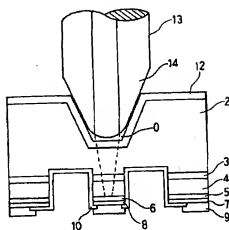
- 9...ボンディングパッド、  
 10...SiN膜、  
 12、29...SiN反射防止膜、  
 13...光ファイバ、  
 14...外部光導体端部、  
 15...回路基板、  
 16...回路パターン、  
 17...半田バンプ、

【図1】

- 20...p-InAlAs層、  
 22...InAlAsP層、  
 23...InAlAs/InGaAs超格子増倍層、  
 24...InAlAs層、  
 25...InGaAsコンタクト層、  
 26...n電極、  
 26...p電極、  
 28...ポリミド層。

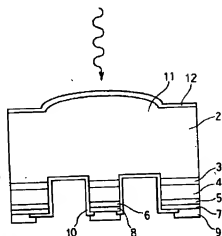
【図2】

図1



- 0...整合光結合穴  
 2...n<sup>+</sup>-InP基板  
 3...InPバッファ層  
 4...InGaAs吸収層  
 5...InPキャップ層  
 6...Zn拡散層  
 7...nコンタクト層  
 8...pコンタクト層  
 9...ボンディングパッド  
 10...SiN膜  
 12...SiN反射防止膜  
 13...光ファイバ  
 14...外部光導体端部

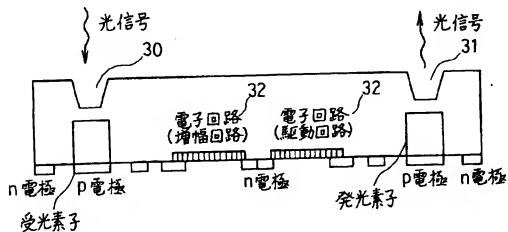
図2



- 2...n<sup>+</sup>-InP基板  
 3...InPバッファ層  
 4...InGaAs吸収層  
 5...InPキャップ層  
 6...Zn拡散層  
 7...nコンタクト層  
 8...コンタクト層  
 9...ボンディングパッド  
 10...SiN膜  
 11...マイクロレンズ  
 12...SiN反射防止膜

【図5】

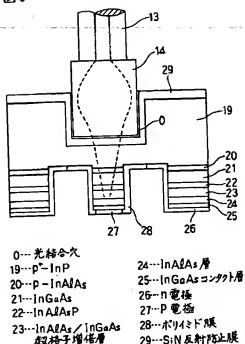
図5



(6)

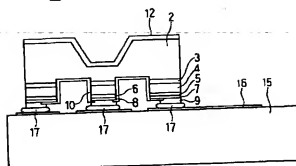
【図3】

図3



【図4】

図4



- 2...n<sup>+</sup>-InP基板  
3...InPバッファ層  
4...InGaAs吸収層  
5...InPキャップ層  
6...Zn拡散層  
7...nコンタクト層  
8...pコンタクト層  
9...ボンディングパッド  
10...SiN膜  
12...SiN反射防止膜  
13...入力光信号  
14...光結合穴  
15...回路基板  
16...電子回路パターン  
17...半導体パッド

【図7】

【図6】

図6

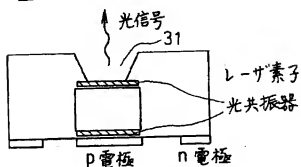
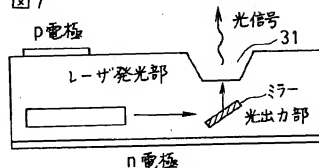


図7



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